little about the mathematical literature. For instance, we find on page 33 of the present volume the statement that mathematical works afford no reply to the question which of the ordinary complex numbers should be regarded as positive and which as negative. The fact is that the terms positive and negative are commonly applied only to real numbers and the reviewer does not see an advantage resulting from the use of these terms in connection with complex numbers as proposed by the authors of this volume. For a very elementary generalization of the terms positive and negative numbers we may refer to volume 15 (1908) of the *American Mathematical Monthly,* page 115.

As regards form the volume under review could have been made more useful by the addition of headings of sections. If the series is continued it is to be hoped that the future volumes will be improved along this line as well as along the line of more complete references and less prolixity in the development of the special views of the authors. While the many shortcomings of the present volume have forced the reviewer to the conclusion that the series will be used by only a small number of mathematicians unless the future volumes should exhibit a marked improvement over the one before us, he recognizes the need of a scholarly work on the general subjects selected by the authors of this volume, and he would like to hope that the later volumes of the series may tend to fill this want.

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Harvey's Views on the Use of the Circulation of the Blood. By JOHN G. CURTIS. Columbia University Press, New York, 1915. 8vo. Pp. 194, 4 pls.

It is a great source of inspiration to feel that one belongs to a goodly company possessing a common ideal and a common interest. What enthusiasm is aroused in us by a great International Congress of scientists! Here the appeal is made to our social sense, but there is a second powerful appeal, that to our historic sense. This comes when we realize that we of to-day are but the visible part of a long line of precursors who have been our teachers and the teachers of our teachers and have handed down through the ages the enthusiasm for knowledge and truth which we consider our dearest heritage. Just as none of us can afford to be provincial, so none of us can afford to neglect the history of scientific thought. That would be to affirm the importance of evolution in theory while denying it in practise.

At this time when proper international relations are interrupted it is a solace to turn from the present to the past and to strengthen our acquaintance with the illustrious scientists of former times. This is especially desirable when we can do so in the company of one whose familiarity with ancient viewpoints makes him a competent expounder of that which time has rendered obscure.

The theme of Professor Curtis's book is clearly stated in the title. To make Harvey's views intelligible to us we are introduced to the illustrious ancients from whom, next to nature, Harvey drew most of his learning or who colored learned opinion in Harvey's time. Harvey's importance as a discoverer has long been recognized, but for a lucid explanation of his place in the history of scientific thought we have waited for this book. Our sincere thanks are due to Professor Lee, who has completed and published the manuscript left by Professor Curtis.

Nutrition.—According to Aristotle and Galen (who borrowed the idea from Plato) the parts feed themselves tranquilly from the blood vessels, which act as irrigating ditches in the garden. So why, asks Harvey, this rush of such great quantities of blood through all parts of the body? Although Harvey recognized that such a mechanism as the circulation was most useful in explaining intestinal absorption in that it did away with the classic belief that in the portal vessels there were two currents, one carrying blood to the intestines and the other carrying absorbed food to the liver, still he could not believe that the sole use of the circulation was the feeding of the parts.

Respiration.—In his quest of the meaning

of the circulation Harvey naturally reviewed what little was known of the respiration in regard to which there were current at this time two ancient beliefs, (1) the refrigerating action and (2) the production of vital spirits. The Hippocratic writers believed that in spite of the obstruction of the semilunar valves some air entered the heart to cool it. Aristotle amplified this view, stating that the action of the air upon the innate heat which had as its origin and seat the heart, was like the action of the air in respect to a fire—it cooled it and prevented too rapid combustion. The second conception was also as old as Hippocrates. It consisted in the belief that something derived from the inspired air (spirits) enters into the heart and thence passes by the vessels to all parts of the body. Aristotle rejected this doctrine and taught that the spirits are not derived from without. When the arteries and veins came to be distinguished and the former were found empty, it was thought that during life the spirits filled the arteries while the blood filled the veins, and when Galen proved that the arteries also contained blood it was at once concluded that this blood, unlike that in the veins, was spirituous.

For a while Harvey held both of these views. Then first he disposed of the notion that the blood received anything from the lungs by observing that the pulmonary veins contain blood only and not blood and air. This conclusion was not justified, since from the same premises Columbus inferred that the concoction of the air and blood to make the spirituous blood takes place in the lungs and that in the pulmonary veins the two are no longer separable. For a longer time Harvey adhered to the refrigerating action of the respiration, but in his old age he was inclined to doubt its importance, for the fetus required no refrigeration of its innate heat. So it was of no use to turn to the respiration for any light as to the uses of the circulation.

Primacy of the Heart.—But might it not be that the body needed heat and spirits from the heart which is, according to Aristotle, the center of heat and of the soul? Aristotle's doctrine of the primacy of heat had been denied by Galen who pointed to the tricuspid valve (of which Aristotle knew nothing) and asked: "How then can the heat be the origin of the veins?" According to Galen the veins arose from the liver and supplied the parts with nutritive blood. The heart, on the other hand, supplied the parts with spirituous blood. The little blood which passed from the right to the left side of the heart did so through invisible pores of the septum. In the left ventricle it became mixed with spirits and passed thence to the aorta and also to the lungs through the mitral valve, which, having but two leaves, was imperfect. The followers of Aristotle (called "philosophers") and those of Galen ("physicians") were soon at odds, each finding the weak points of the other's doctrine. In Galenism were the pores in the septum and the imperfection of the mitral valve; while, on the other hand, the tricuspid was the stumbling block of the Aristotelians.

By his discovery of the pulmonary path for the blood Columbus materially aided the Galenists, who might now abandon the idea that blood sweats through pores in the septum. When Harvey demonstrated the circulation and thus explained the use of the atrioventricular valves, he regarded himself as defending Aristotle's doctrine of the primacy of the heart and hence his remark regarding his opponent Riolanus, "It is proper that the dean of the College of Paris should keep the medicine of Galen in repair; and should admit no novelties into his school without the utmost winnowing."

Primacy of the Blood.—Aristotle believed that the heart was the center of life, the source of heat and the abode of the soul. But to the discoverer of the circulation the primacy of the heart began very early to give place to the primacy of the blood until in his latest utterances the heart is merely the servant of the blood, of use to pump it along but contributing to the blood nothing but motion. Harvey supported this novel view by observation. He believed that he saw in the chick embryo first the blood which presently began to pulsate by itself and only later the developing heart.

Aristotle had set forth a principle that those

parts which first manifest life are those which die last. Harvey thought this to be true of the blood, for he mistook the fibrillation of the auricle in the otherwise quiescent heart for an "obscure motion and flow and a sort of palpitation manifestly . . . in the blood itself," and furthermore he observed that animals without a pulse but which possess blood might continue to live.

Cause of the Heart Beat.—But Harvey was not willing to attribute to his new-found pump the importance which it deserved, as is seen from his views in regard to the cause of the heart's beat. To be sure, the most important cause of the return of the blood to the heart is the systole of the heart (and of the arteries) which continually stuff with blood the porosities of the parts. To this is added the muscular movements of the limbs, etc., and in the case of the pulmonary circulation the collapse of the lungs. But when it comes to the dilatation of the auricles the pump gives out and Harvey finds it necessary to endow the blood with a property (ebullition) borrowed from Aristotle. This dilatation of the auricles is an event of great importance to the circulation. Harvey saw in it, as we shall see, the cause of the heart beat. Aristotle knew nothing of contractility of muscle and was therefore obliged to attribute not only the diastole of the heart, but also its systole to the action of the blood which boiled, rising and falling within the heart. Since the time of Galen, however, the power of contraction had been recognized in muscle and consequently Harvey made use of this doctrine in interpreting the action of the heart. To Harvey the cause of the ventricular beat was the mechanical distension of the ventricle through the contraction of the auricle. But what distended the auricle? The power of ebullition of the hot blood (already referred to) acting "in the vena cava close to the base of the heart and to the right auricle." But how, we ask, did Harvey explain the simultaneous contraction of both auricles and how did he reconcile this view with the long-known fact (often referred to by him) that excised and bloodless hearts may continue to beat. In regard to the first, he only remarked that the simultaneous movement of the two eyes is a comparable phenomenon. But as to the second he says nothing whatever.

The Innate Heat.—Let us look more closely at the nature of the "innate heat" and "the soul" which Aristotle placed in the heart and Harvey in the blood. Aristotle was convinced that fire is sterile, while animal heat is generative and that therefore the heat of animals is quite distinct from elemental fire. In the simplest form of generation (the spontaneous) the soul is derived from the air and the heat from the sun. The solar heat is therefore generative and more akin to vital heat than to fire. Again, in sexual generation the vital heat and the soul are conveyed in the semen, but nevertheless the solar heat must be added "for the cause of man is his father, the sun, and the ecliptic" (that is the sun and its motions). The heat of animals is analogous to the ether, the fifth and superior element from which the heavenly bodies, including the sun, are made. But strangely inconsistent, he adds that the heat of the sun is born of friction and is not ethereal.

Harvey agrees with Aristotle that the animal heat is not fire nor derived from fire. He, too, believed that the sun in its motions generates acting through the semen of the male, that in generation the heat and soul are transmitted in the semen but find their abode during life not in the heart but in the blood.

We have seen that Harvey was no mere imitator of his great and revered master, Aristotle, that he was an observer and thinker of great originality and independence. It is equally interesting to note in closing his attitude toward the discoveries of others. The Copernican astronomy he treated as still *sub judice*. He paid no attention to the discovery by Aselli of the lacteals.

> He did not care for Chymistrey and was wont to speake against them (the chemists) with an undervalue.

In rejecting the view of Columbus he lost a valuable clue as to the nature of the respiration.

On reaching the end of this little volume one is seized with regret not only that the book

itself has come to an end, but that the work of the author is finished too. There are many who can carry forward investigations and complete new discoveries, but there are very few who are made competent by their thorough scholarship to understand, and through their delightful style to explain, the evolution of scientific thought from one age to another.

Percy M. Dawson

SPECIAL ARTICLES

THE PROCESS OF FEEDING IN THE OYSTER

A valuable contribution to knowledge of the ciliary mechanisms of Lamellibranch mollusks has been made by James L. Kellogg in Vol. 26, No. 4, of the *Journal of Morphology*.

In this paper Dr. Kellogg brings together, with numerous illustrations, his observations on the ciliary tracts of structures found within the mantle chamber of thirty-one species of lamellibranchs.

In each case the observations were made on the animal after one of the valves of its shell had been removed, and the presence and direction of ciliary currents were determined by means of powdered carmine, fine black sand or masses of diatoms, deposited upon the parts under observation.

Among the several conclusions at which Dr. Kellogg arrives as a result of his study concerning the activities and functions of these tracts of cilia, the following, published on pages 699 and 700, are those to which the "oral exceptions," referred to by Dr. Kellogg on page 640, have been taken and they are the ones also which will be called in question in this paper:

1. Volume alone determines whether the collected foreign matter that reaches the palps shall proceed to the mouth or shall be sent from the body on outgoing tracts [of cilia].

2. A Lamellibranch is able to feed only when waters are comparatively clear—when diatoms are brought to the gill surfaces a few at a time. In muddy waters, all suspended particles, of whatever nature, are led to outgoing tracts.

3. There is no selection or separation of food organisms from other water-borne particles.

4. The direction of the beat of cilia is never changed.

The exceptions taken to these statements were not based, as Dr. Kellogg states, on the fact that the waters over Chesapeake oyster beds are normally muddy for long periods of time or upon the fact that the stomach contents of oysters always contain a larger volume of sand than of food organisms, although both of these facts are difficult to explain on the Kellogg theory, but they are based primarily upon the results of experiments, to be described later, which show that oysters can and do feed rapidly and continuously in waters that are turbid with sediment.

Before passing to a consideration of the results of these experiments, however, which bear directly upon the *first* and *second* only of Dr. Kellogg's conclusions (as numbered in this paper), reference may be made to the findings of other observers not in agreement with those of Dr. Kellogg, which indicate that the conclusions numbered (3) and (4) were possibly drawn from an insufficient basis of observation or that the methods of study employed by Dr. Kellogg were not designed to reveal *all* of the activities of the ciliary mechanisms of lamellibranchs.

REVERSAL OF CILIA AND FOOD SELECTION

In Stentor, Schaeffer[1] has shown that there is a selection of food particles brought about by changes in the beat of the cilia of the pouch and funnel, certain particles being rejected by a localized reversal of the cilia. He also found that the behavior of the animal toward food is not the same when it is in a condition of hunger as when in a condition of satiety.

Stentor is not an isolated example of protozoan possessing the power of food selection and rejection exercised through the control of the ciliary mechanism of the mouth region. Numerous other cases might be cited.

Cases of reversal of cilia are also reported among metazoan animals, Parker[2] having found that in *Metridium* the cilia on the lips, which normally beat outward, can be made to

[1] Asa Arthur Schaeffer, "Selection of Food in *Stentor cæruleus*," *Jour. Exp. Zool.*, 1910.

[2] G. H. Parker, "The Reversal of Ciliary Movements in Metazoans," *Am. Jour. of Physiology*, Vol. XIII., 1905.